Water Management in Ontario

RESEARCH
PUBLICATION
NO. 38

GAMMA IRRADIATION OF SEWAGE AND SEWAGE SLUDGES

THE ONTARIO WATER RESOURCES COMMISSION

CA2 ON
EV.506
R38

GAMMA IRRADIATION

OF

SEWAGE

AND

SEWAGE SLUDGES

By:

N. Ehlert

July, 1971

Division of Research
Publication No. 38

A. J. Harris
Director

R. D. Johnston
Chairman

D. S. Caverly
General Manager

The Ontario Water Resources Commission

- NOTICE -

SUMMARY

The Division of Research of the Ontario Water Resources Commission, in cooperation with Atomic Energy of Canada (Commercial Products), has completed a laboratory study on the effects of gamma irradiation on sewage and sewage sludges. The study primarily consisted of jar tests to determine maximum sludge volume reduction with minimum effects on supernatant quality due to irradiation. Dynamic tests to observe changes in sewage biodegradability as a result of irradiation were also run. Four different dose rates were used ranging from 60 to 35,500 rads per minute.

Conclusions reached concerning use of gamma irradiation as a sewage sludge conditioner were:

1. low rate irradiation (60 and 630 rads/min) was not effective in reducing sludge volume.

2. higher rate irradiation (7,100 rads/min) significantly reduced sludge volume at a total dose of 10^6 rads. The settling rate of waste activated sludge was improved at all doses.

3. Optimum doses for improved settling with high rate irradiation (35,500 rads/min) were 10^6 rads for raw sewage and between 5×10^4 and 10^5 rads for sewage sludges.

Results of dynamic tests for sewage biodegradability were inconclusive. Sewage and sludges from different plants did not respond identically to the same dosages of irradiation.

TABLE OF CONTENTS

LIST OF FIGURES

I INTRODUCTION

As part of a continuing program to evaluate new methods of wastewater treatment, the OWRC Division of Research, in cooperation with Atomic Energy of Canada, (Commercial Products), initiated a study on the effects of gamma irradiation on sewage treatment processes.

Radiation has the ability to alter the structure of organic and inorganic materials, initiate oxidation in organics, kill bacteria and other micro-organisms, and produce electrical effects in colloidal systems (1). In sewages, the above properties could enhance the biodegradability of refractory pollutants, reduce biochemical oxygen demand (BOD), destroy bacteria and virus, and improve settleability of sludges.

Gamma irradiation for waste treatment was considered more suitable than alpha or beta for both sociological and functional reasons. Gamma rays do not cause radioactive contamination of the irradiated medium which could jeopardize the environment; they follow an exponential rather than linear absorption curve and their relatively short wavelength allows much greater penetrability than the particulate types of radiation.

Investigations pertaining to the use of gamma irradiation in waste treatment have been contracted to Battelle Memorial Institute (Dr. C. J. Touhill) and to Purdue University (Dr. J. Etzel)

by the Metropolitan Sanitary District of Greater Chicago (2). Results from settleability tests by the Purdue group (3) effected little reduction in volume of digested waste activated sludge while irradiation of waste activated sludge resulted in a 2.5 concentration factor in solids in about 50 minutes with a dose between 175,000 and 200,000 rads. A corresponding increase in supernatant turbidity and COD was noted with increased radiation dosage. The Battelle results (4) showed that cyanide and phenol in the waste could be readily degraded to innocuous end-products. Studies by Compton et al (5) with mixed liquor indicated an approximate 25 percent improvement in settling velocity and sludge volume index (SVI) at 5×10^5 rads. Filterability of digested and raw sewage was improved with irradiation. No synergism was found between chemical conditioning agents and irradiation.

Investigations conducted by the OWRC Division of Research used raw sewage and sewage sludges from treatment plants with influents of varied domestic and industrial waste content. The purpose was to determine an optimum dose rate or total dose of gamma irradiation for increased sludge settleability and sewage biodegradation. A minimum number of tests were made with pure colloidal substrates as it was felt that little correlation would be found between this medium and relatively complex raw sewage.

II EXPERIMENTAL CONDITIONS

1. Irradiation Facilities

The irradiation facilities consisted of two sets of Gammacells* loaded and installed by Atomic Energy of Canada Limited. The two types used, Models 200 and 220, were loaded with Cobalt 60 sources of gamma irradiation.

A cylindrical drawer can be raised or lowered into a lead-shielded annular source. A chamber in the drawer allows samples to be inserted outside the radioactive area and lowered into the source. A digital timer may be preset to give the required exposure and automatically raise the drawer at the end of the irradiation period.

The loading and initial dose rate of the Gammacells used were:

Gammacell	Loading	Dose Rate
GC 200	23.5 Curies	3,660 rads/hr
GC 200	236. Curies	42,500 rads/hr
GC 220	4,800 Curies	450,000 rads/hr
GC 220	26,285 Curies	2,220,000 rads/hr

The sources decay at a rate of approximately 1 percent per month, and the irradiation period to achieve the same total dose was increased correspondingly.

* Registered Trademark - AECL

Samples of 1000 mls. could be handled by the GC 220, and 500 mls. by the GC 200. For dynamic tests, sewage was pumped through polyethylene tubing to a copper coil placed in the radiation chamber.

2. Laboratory Facilities

Raw domestic sewage from Rexdale was obtainable from a pipeline in the laboratory. Sufficient raw sewage and sewage sludge for a two day working period was collected from local treatment plants and kept refrigerated overnight. Liquors from Brampton, Lakeview, Newmarket, and Richmond Hill Water Pollution Control Plants (WPCP) were tested. A model sewage treatment plant (6) which closely duplicated the activated sludge process was used for dynamic tests using Rexdale raw sewage as feed.

III RESULTS

1. Raw Sewage

1.1 Experimental Procedure

Raw sewage was collected every second day from the primary influent channel at the Brampton and Lakeview WPCP while Rexdale sewage was taken directly from the OWRC laboratory pipeline. Brampton and Rexdale sewage was mainly domestic in nature; Lakeview contained a large percent of industrial waste.

Five hundred milliliter samples in polyethylene bottles were irradiated at each dose rate over the following total dose ranges.

Gammacell	Dose Rate (rads/min)	Dose Range (rads)
GC 200	60	10 - 10^4
GC 200	630	10^2 - 10^6
GC 220	7,100	10^3 - 10^7
GC 220	35,500	10^4 - 10^7

The samples were mixed by inversion and settled for 30 minutes alongside controls in snub-nosed Imhoff cones. The settled solids volumes of all samples were recorded and the supernatants drawn off using a diaphragm pump. The supernatants were submitted for physical (suspended and total solids) and chemical (BOD, COD, Nitrogen) determinations.

1.2 Results

A statistical analysis of the results obtained from irradiation of raw sewage is presented in Table 1. A graphical presentation of data is made in Figures 1 and 2. Settled solids volume in the controls was equated to one hundred percent; any change in volume as a result of irradiation was expressed as a percentage of the original value.

The Student "t" test was used with a 95 percent confidence level to predict whether irradiation had a significant effect on the reduction of settled solids volume. Since this confidence level was approximately equal to the range covered by the variance, only the latter parameter was included in the results.

The inconsistent nature of raw sewage and the relatively small volume of settleable solids contained in it, averaging between 0.2 and 1.0% sludge volume, meant that a 0.5 ml difference in volume due to irradiation could result in a 50 percent change compared to a control. This could explain the rather erratic results and the ranges necessary to justify the desired confidence level.

The lowest irradiation rate (Table 1.1) was ineffective in reducing settled solids volume over the entire dose range. A tenfold increase in dose rate (Table 1.2) showed a similar lack

DATA FOR RAW SEWAGE

Table 1

1.1 Dose Rate - 60 rads/min (GC 200)

Source	Dose (Rads)	10	50	10^2	$5x10^2$	10^3	$5x10^3$	10^4
Lakeview	No. Samples	6	6	6	6	6	7	7
WPCP	% Original Settled Volume	101.	106.	93.	105.	111.	102.	93.
	Variance	±42.	±37.	±42.	±35.	±20.	±40.	±49.
Brampton	No. Samples	8	5	10	5	9	5	11
WPCP	% Original Settled Volume	106.	96.	100.	86.	91.	97.	84.
	Variance	±20.	±46.	±36.	±50.	±31.	±46.	±14.
Rexdale	No. Samples	6	5	6	5	8	6	8
	% Original Settled Volume	99.	122.	108.	113.	101.	83.	110.
	Variance	±13.	±24.	±31.	±12.	± 9.	±18.	±29.

1.2 Dose Rate - 530 rads/min (GC 200)

Source	Dose (Rads)	10^2	10^3	10^4	$5x10^4$	10^5	$5x10^5$	10^6
Lakeview	No. Samples	18	16	13	4	6	4	1
WPCP	% Original Settled Volume	95.	93.	105.	113.	94.	140.	157.
	Variance	±20.	±27.	±16.	±15.	±18.	±12.	--
Brampton	No. Samples	10	13	12	12		6	2
WPCP	% Original Settled Volume	92.	94.	103.	88.		117.	136.
	Variance	±32.	±16.	±24.	±24.		±17.	±20.

Cont....

of effectiveness up to a dose of 10^5 rads. Increasing the total dose above this level produced an increase in settled solids volume. An examination of the results of suspended and total solids determinations from the settled sewage supernatants showed no significant change in these parameters between the irradiated and control samples at all dose levels. Biochemical Oxygen Demand (BOD) determinations on the supernatants were equally invariant.

Higher rate irradiation reduced the settled solids volume between 10 and 20 percent at 10^6 rads total dose (Table 1.3, Figure 1). Results below this value were not sufficiently consistent to base any opinions thereon, while data obtained from irradiating sewage at values greater than 10^6 rads indicated a physico-chemical alteration of the sewage resulting in a bulkier sludge. Changes in supernatant suspended solids and BOD were within the limits of experimental error.

The highest rate irradiation produced a consistent decrease in settled solids volume with increased dosage (Table 1.4, Figure 2). There was no major change in supernatant characteristics except at $5x10^6$ rads where BOD underwent an approximate 25 percent reduction while an equivalent increase in suspended solids concentration occurred.

Table 1 (Cont'd)

1.3 Dose Rate - 7,100 rads/min. (GC 220)

Source	Dose (Rads)	10^3	10^4	10^5	$5x10^5$	10^6	$5x10^6$	10^7
Brampton WPCP	No. Samples	8	7	11	3	9	5	1
	% Original Settled Volume	100.	102.	114.	93.	91.	134.	161.
	Variance	±25.	±25.	±17.	±12	±44.	±23.	--
Rexdale	No. Samples	15	13	11		9	4	2
	% Original Settled Volume	108.	82.	88.		79.	128.	156.
	Variance	±21	±37.	±12.		±15.	±40.	±38.

1.4 Dose Rate - 35,700 rads/min. (GC 220)

Source	Dose (Rads)	10^4	$5x10^4$	10^5	$5x10^5$	10^6	$5x10^6$	10^7
Brampton WPCP	No. Samples	10	5	11	5	9	5	
	% Original Settled Volume	116.	89.	89.	66.	52.	81.	
	Variance	±54.	±26.	±18.	±27.	±28.	±19.	
Lakeview WPCP	No. Samples	6	7	7	6	7	7	
	% Original Settled Volume	111.	109.	98.	75.	65.	45.	
	Variance	±13.	±29.	±20.	±30.	±11.	±17.	
Rexdale	No. Samples	6	7	8	5	8	6	2
	% Original Settled Volume	96.	93.	108.	27.	42.	21.	42.
	Variance	±12.	± 9.	±16.	±22.	±64.	±20.	±12.

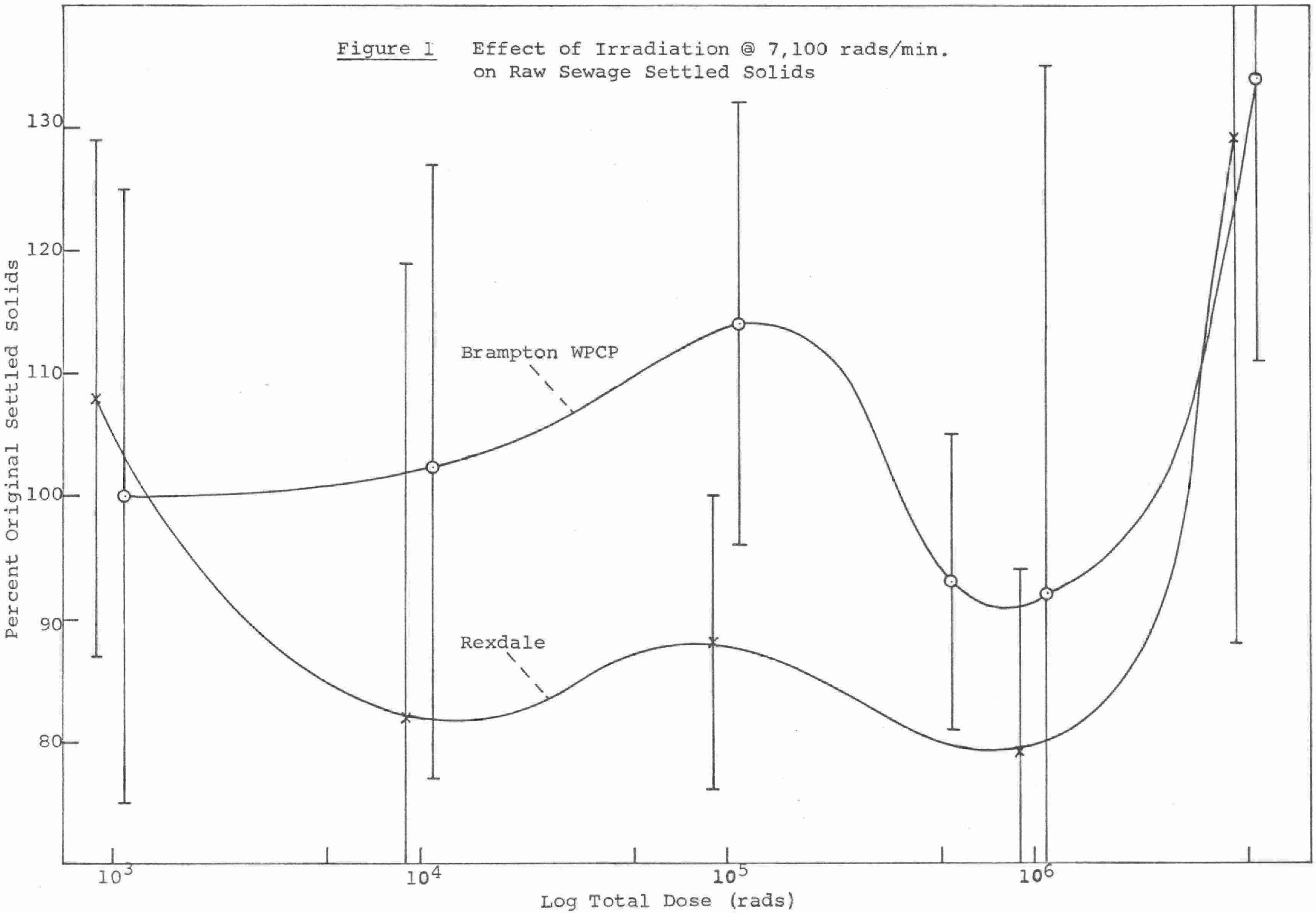


Figure 1 Effect of Irradiation @ 7,100 rads/min. on Raw Sewage Settled Solids

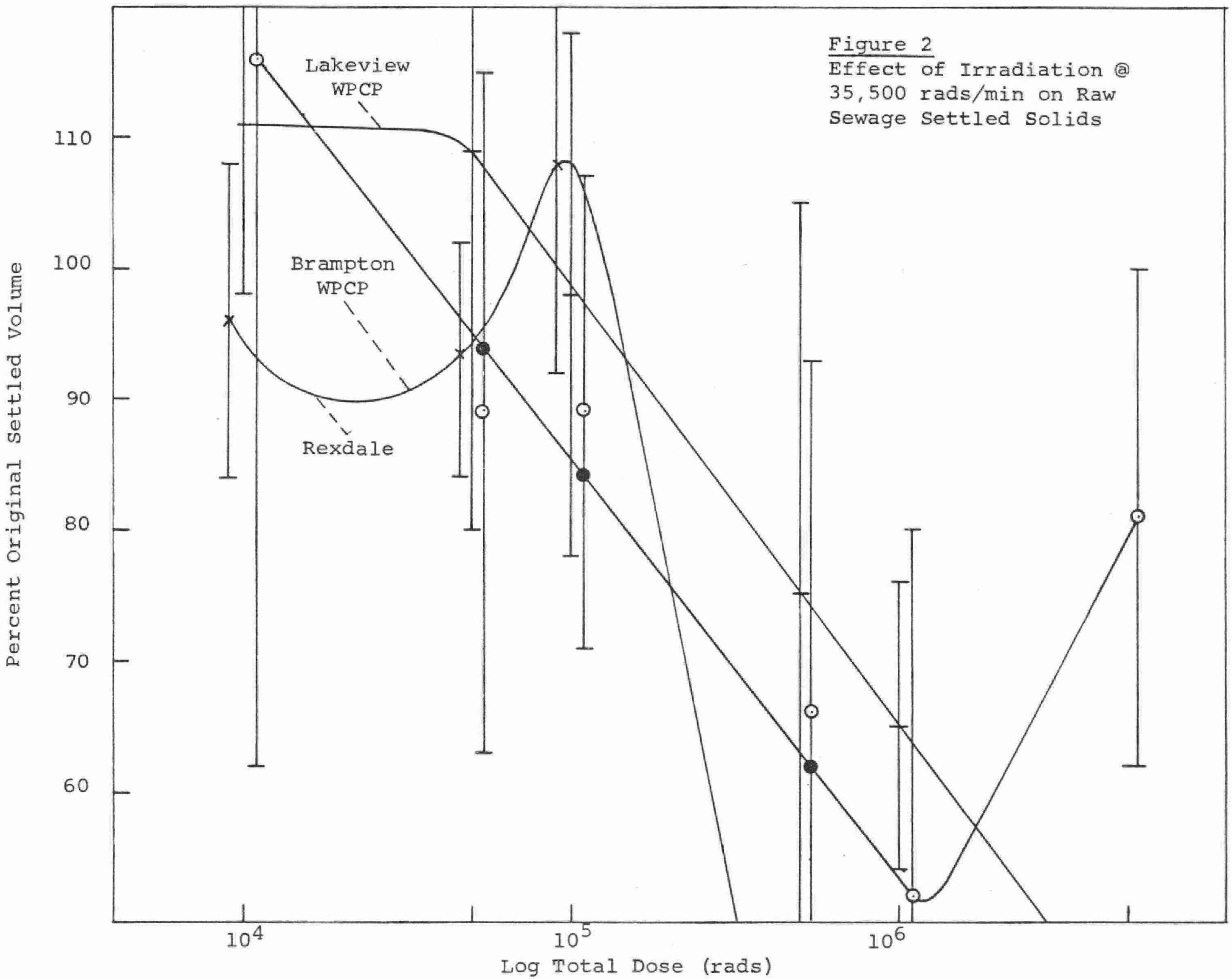


Figure 2
Effect of Irradiation @ 35,500 rads/min on Raw Sewage Settled Solids
Lakeview WPCP
Brampton WPCP
Rexdale
Percent Original Settled Volume
110
100
90
80
70
60
10^4
10^5
10^6
Log Total Dose (rads)

None of the dose rates used in this study produced any significant change in sewage settled solids volume below a total dose of 10^5 rads. As the dose rate increased, the total dose necessary to effect reduction in solids volume increased. Above the point of maximum reduction, some physical or chemical alteration of the sewage resulted in a decrease in solids compacting with no significant change in supernatant characteristics. There could be a correlation between exposure time in the Gammacells and maximum volume reduction because at the lower rate approximately 160 minutes were required and at the two higher rates, 140 minutes. This suggests that there was an optimum time needed to effect coalescence of the sludge particles in the presence of irradiation,

2. Sewage Sludges

2.1 Experimental Procedure

Sewage Sludges were obtained from several treatment plants (Brampton, Lakeview, Newmarket and Richmond Hill) and pilot scale plants in the OWRC laboratories. A sufficient number of observations were made on irradiated samples of mixed liquor (secondary clarifier influent), waste activated sludge (primary clarifier influent) and digested sludge (secondary digester influent) to permit a statistical analysis of the effect of gamma irradiation on sludge volume reduction. The quality (BOD and suspended solids) of the supernatant from the settled samples was determined to check whether a reduction in sludge volume was a result of sludge dispersion or compaction.

Standard 500 ml. samples of the sludges were irradiated in each of the Gammacells and settled alongside controls in 500 ml. graduate cylinders. Because sludge samples were collected regularly (once every two days), the flotation of some sludges at particular doses was accredited to a physico-chemical alteration of the sludges due to irradiation rather than septicity.

2.2 Results

2.2-1 Mixed Liquor

A statistical analysis of the results obtained from low and high rate irradiation of mixed liquor is presented in Table 2. Settled solids volume of the controls was equated to 100 percent with the change in volume due to irradiation expressed as a percentage of this value.

The average values of the observed parameters before irradiation were:

	Percent Settled Sludge Volume	Supernatant SS (ppm)	Supernatant BOD (ppm)
Brampton	20	49	48
Lakeview	26	219	191

Low rate irradiation (59 rads/min) produced no statistically significant reduction in sludge volume over the entire dose range (Table 2.1). No significant changes in supernatant characteristics (BOD, Total and Suspended Solids) occurred.

High rate irradiation (35,100 rads/min) showed some beneficial sludge volume reduction between $5x10^4$ and 10^5 rads in the Lakeview liquor with little change in supernatant quality (Table 2.2). Above 10^5 rads, almost complete flotation of the sludge was induced with minimum sedimentation. As the dosage increased, the floating sludge volume decreased to approximately 10 percent of its original

DATA FOR MIXED LIQUOR

Table 2

2.1 Dose Rate - 59 rads/min. (GC 200)

Source	Dose (Rads)	10	50	10^2	$5x10^2$	10^3	$5x10^3$	10^4
Brampton	No. Samples	6	4	6	4	6	4	5
	% Original Sludge Volume	95.	97.	99.	99.	91.	92.	94.
	Variance	± 6.	± 2.	± 5.	± 4.	± 7.	±24.	± 6.
Lakeview	No. Samples	4	4	4	4	3	4	5
	% Original Sludge Volume	100.	101.	108.	140.	115.	96.	96.
	Variance	±24.	±17.	±27.	±30.	±24.	±14.	±28.

2.2 Dose Rate - 35,100 rads/min. (GC 220)

Source	Dose (Rads)	10^4	$5x10^4$	10^5	$5x10^5$	10^6	$5x10^6$
Brampton	No. Samples	6	2	4	4	5	4
	% Original Sludge Volume	87.	--	94.	All	Sludges	Floated
	Variance	± 8.	--	±10.			
Lakeview	No. Samples	3	4	5	3	2	3
	% Original Sludge Volume	121.	75.	67.	All	Sludges	Floated
	Variance	±24.	±18.	±23.			

volume. The supernatants of the samples with floating sludge increased approximately 100 percent in BOD and suspended solids.

Within the confines of the present activated sludge sewage treatment system, floating mixed liquor suspended solids would be detrimental to proper plant operation in both primary and secondary sedimentation tanks. The increase in BOD and suspended solids in the supernatant, probably caused by sludge dispersion due to irradiation, would also be unacceptable in a sewage treatment plant effluent.

The reasons for flotation could be:

1. Radiation-induced denitrification forming nitrogen gas bubbles which floated the sludge.

2. Release of dissolved oxygen due to increase in temperature resulting from the heat within the radiation cell lending buoyancy to the sludge.

At high dosages a decrease in nitrite (NO_2) and nitrate (NO_3) was observed but this was not conclusive.

The reason for the greater sludge volume reduction in the Lakeview mixed liquor suspended solids could be due to the much greater percent of industrial wastes in the stream. A more extensive study of treatment plants with high percent industrial influents would have to be made before concluding that irradiation is beneficial to this type of waste.

2.2-2 Waste Activated Sludge

A summary of the data obtained from irradiating waste activated sludge at low and high rates was made in Table 3. Graphical analyses of particular sets of results from the low, intermediate and high ranges were made to indicate trends due to irradiation in Figures 3, 4 and 5. All results were based on measuring the sludge volume and supernatant BOD and suspended solids of irradiated samples and comparing them to controls whose properties were considered unaltered.

The average values of the particular parameters before irradiation were:

	Percent Settled Sludge Volume	Supernatant Suspended Solids (ppm)	Supernatant BOD (ppm)
Brampton	67	85	104
Newmarket	52	74	107

Low dose rate irradiation had no significant effect on sludge volume reduction below a total dose of 10^3 rads. Between $5x10^3$ and 10^4 rads, the Brampton sludge volume dropped between 15 to 25 percent of the control value with a similar decrease in supernatant suspended solids (Table 3.1, Fig. 3). A slight increase in BOD was also observed in this range.

Higher rate irradiation was used to study the effect on sludge settling rate with increased total dose. Although the percent settled solids in the total volume showed different absolute

DATA FOR WASTE ACTIVATED SLUDGE

Table 3

3.1 Dose Rate - 57 rads/min. (GC 200)

Source	Dose (Rads)	10	50	10^2	$5x10^2$	10^3	$5x10^3$	10^4
Brampton	No. Samples	5	5	5	5	6	7	7
WPCP	% Original Sludge Volume	95.	103.	101.	100.	92.	86.	78.
	Variance	± 6.	±11.	± 7.	± 6.	±17.	±11.	±16.
	% Original Suspended Solids	138.	114.	75.	70.	104.	80.	83.
	Variance	±50.	±40.	±37.	±40.	±22.	±41.	±40.
Newmarket	No. Samples	7	7	7	7	7	7	7
WPCP	% Original Sludge Volume	100.	100.	95.	100.	102.	98.	103.
	Variance	± 5.	±11.	± 9.	± 7.	± 5.	± 6.	± 8.
	% Original Suspended Solids	89.	92.	96.	104.	110.	107.	93.
	Variance	±21.	±26.	±32.	±27.	±15.	±57.	±20.

3.2 Dose Rate - 34,000 rads/min. (GC 220)

Source	Dose (Rads)	10^4	$5x10^4$	10^5	$5x10^5$	10^6	$5x10^6$
Brampton	No. Samples	6	7	7	1	1	--
WPCP	% Original Sludge Volume	83.	82.	73.	60.	46.	--
	Variance	± 9.	±27.	±21.	Sludge Flotation		
	% Original Suspended Solids	98.	138.	96.	195.	521.	482.
	Variance	±23.	±107.	±25.	±95.	±386.	±271.
Newmarket	No. Samples	6	6	7	2	2	---
WPCP	% Original Sludge Volume	103.	96.	96.	84.	58.	Sludge
	Variance	±16.	± 8.	± 8.	± 6.	±34.	Flotation
	% Original Suspended Solids	118.	118.	131.	407.	507.	533.
	Variance	±39.	±40.	±12.	±252.	±300.	±345.

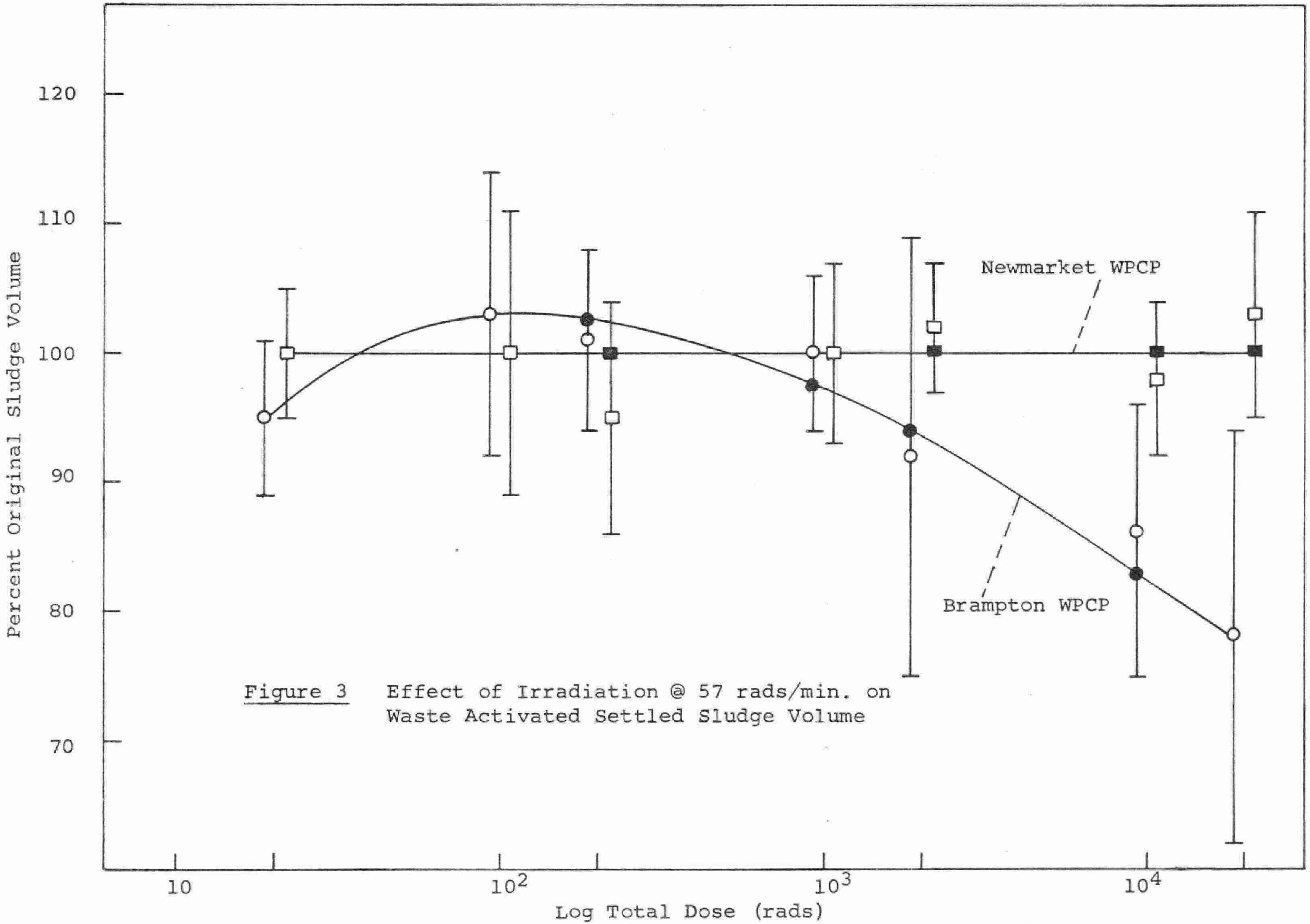
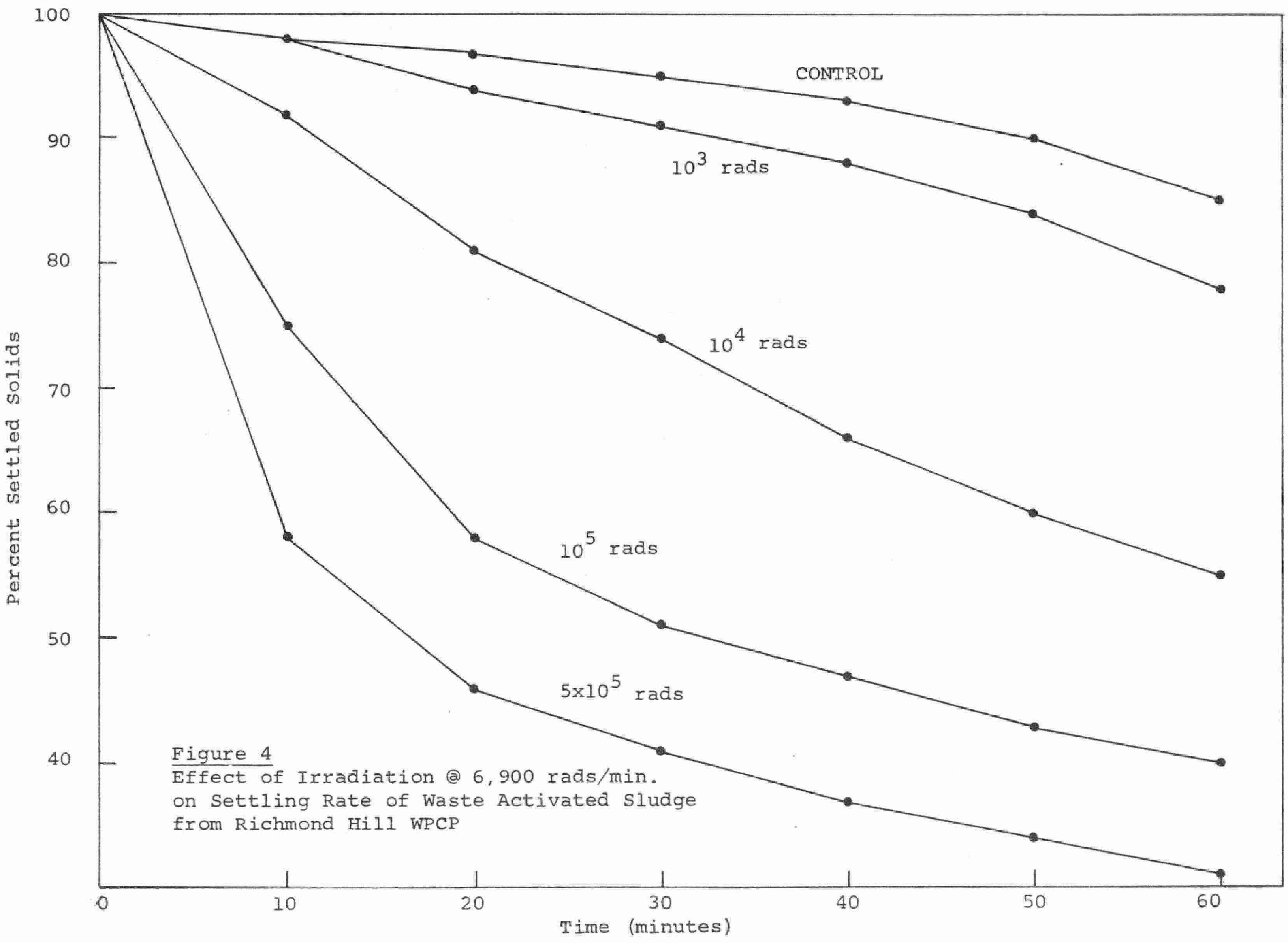


Figure 3 Effect of Irradiation @ 57 rads/min. on Waste Activated Settled Sludge Volume

values on different days, the relative change in settling rates was similar. As can be seen in Figure 4, even a dose of 10^4 rads produced a noticeable increase in settling rate.

Higher rate irradiation produced a consistent decrease in sludge volume between 10^4 and 10^5 rads (Table 3.2). Above this dosage the sludge usually split into a floating and settling fraction with clear liquid between the two masses. Although the data obtained from settling tests on the floating samples was statistically unreliable above 10^5 rads, it was included in a least squares regressional analysis for a straight line relationship. The result, plotted in Figure 5, showed sludge volume reduction to be a linear function of increased radiation dosage. Analysis of the supernatant showed no change in BOD and suspended solids between 10^4 and 10^5 rads; above this dosage the results were quite high and scattered. This could be due to breakdown and dispersion of the sludge particles.

The difference in response between the Newmarket and Brampton sludges might be a result of operating techniques at each plant. A more compact sludge will undergo a smaller percent change as a result of some stimulus such as gamma irradiation whereas a less compact sludge would show a greater response.



<u>Figure 4</u>
Effect of Irradiation @ 6,900 rads/min.
on Settling Rate of Waste Activated Sludge
from Richmond Hill WPCP

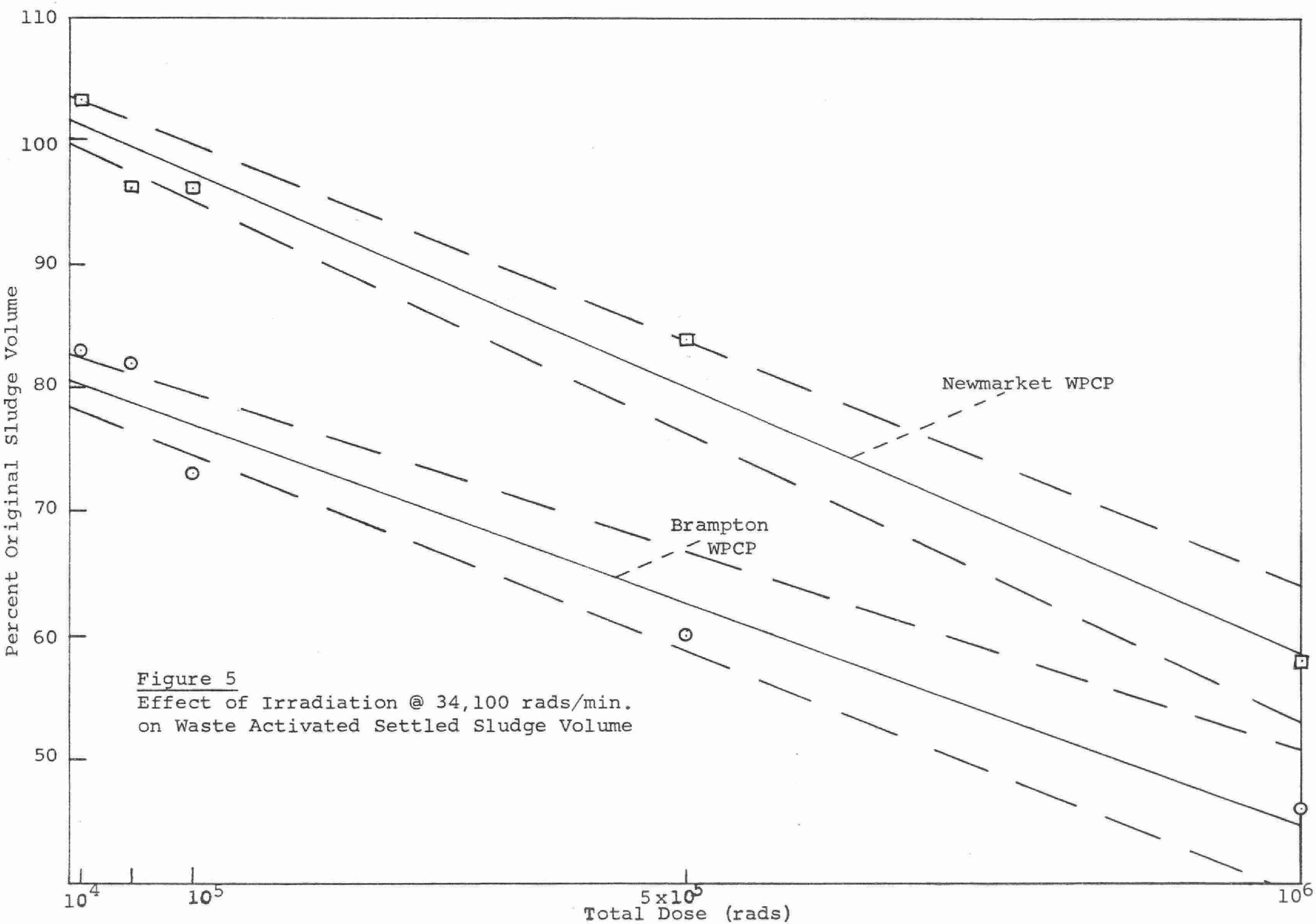


Figure 5
Effect of Irradiation @ 34,100 rads/min. on Waste Activated Settled Sludge Volume

2.2-3 Digested Sludge (Secondary Digester Influent)

A summary of the data obtained from irradiating digested sludge at low and high rates is made in Table 4, a graphical analysis of the results in Figure 6. All data are expressed as a percentage of the control values.

The average values of the control settled sludge volumes and supernatant suspended solids were:

	Percent Settled Sludge Volume	Supernatant SS (ppm)
Brampton	96	---
Newmarket	62	475

The tabulated results from low rate irradiation of digester sludge (Table 4.1) showed that radiation at this dose rate had no effect on sludge volume reduction. The Brampton sludge showed little settling, with and without aid, and suspended solids analyses of the supernatant were impossible due to the small volume obtained.

High rate irradiation showed more promise as a means of sludge volume reduction, particularly with the Newmarket digester influent. A least squares regressional analysis of the data again showed a linearity between sludge volume reduction and increased radiation dosage (Table 4.2, Fig. 6). Although a 45 percent reduction in sludge volume was obtained at maximum

DATA FOR DIGESTED SLUDGE

Table 4

4.1 Dose Rate - 57 rads/min. (GC 200)

Source	Dose (Rads)	10	50	10^2	$5x10^2$	10^3	$5x10^3$	10^4
Brampton	No. Samples	7	7	7	7	7	7	7
WPCP	% Original Sludge Volume	101.	101.	100.	100.	102.	100.	100.
	Mean Deviation	± 1.	± 2.	± 1.	± 1.	± 3.	± 1.	± 1.
Newmarket	No. Samples	6	6	6	6	7	6	5
WPCP	% Original Sludge Volume	98.	99.	96.	102.	96.	105.	94.
	Mean Deviation	± 5.	± 4.	± 5.	± 6.	± 7.	±13.	± 5.

4.2 Dose Rate - 34,300 rads/min. (GC 220)

Source	Dose (Rads)	10^4	$5x10^4$	10^5	$5x10^5$	10^6	$5x10^6$
Brampton	No. Samples	7	7	7	7	7	7
WPCP	% Original Sludge Volume	103.	100.	100.	97.	98.	91.
	Mean Deviation	± 5.	± 1.	± 1.	± 6.	± 3.	±15.
Newmarket	No. Samples	7	6	6	5	6	4
WPCP	% Original Sludge Volume	94.	107.	86.	84.	81.	57.
	Variance	± 8.	±36.	±13.	± 7.	± 7.	± 8.
	% Original Suspended Solids	106.	110.	110.	134.	176.	239.
	Variance	±12.	±26.	±16.	±24.	±46.	±145.

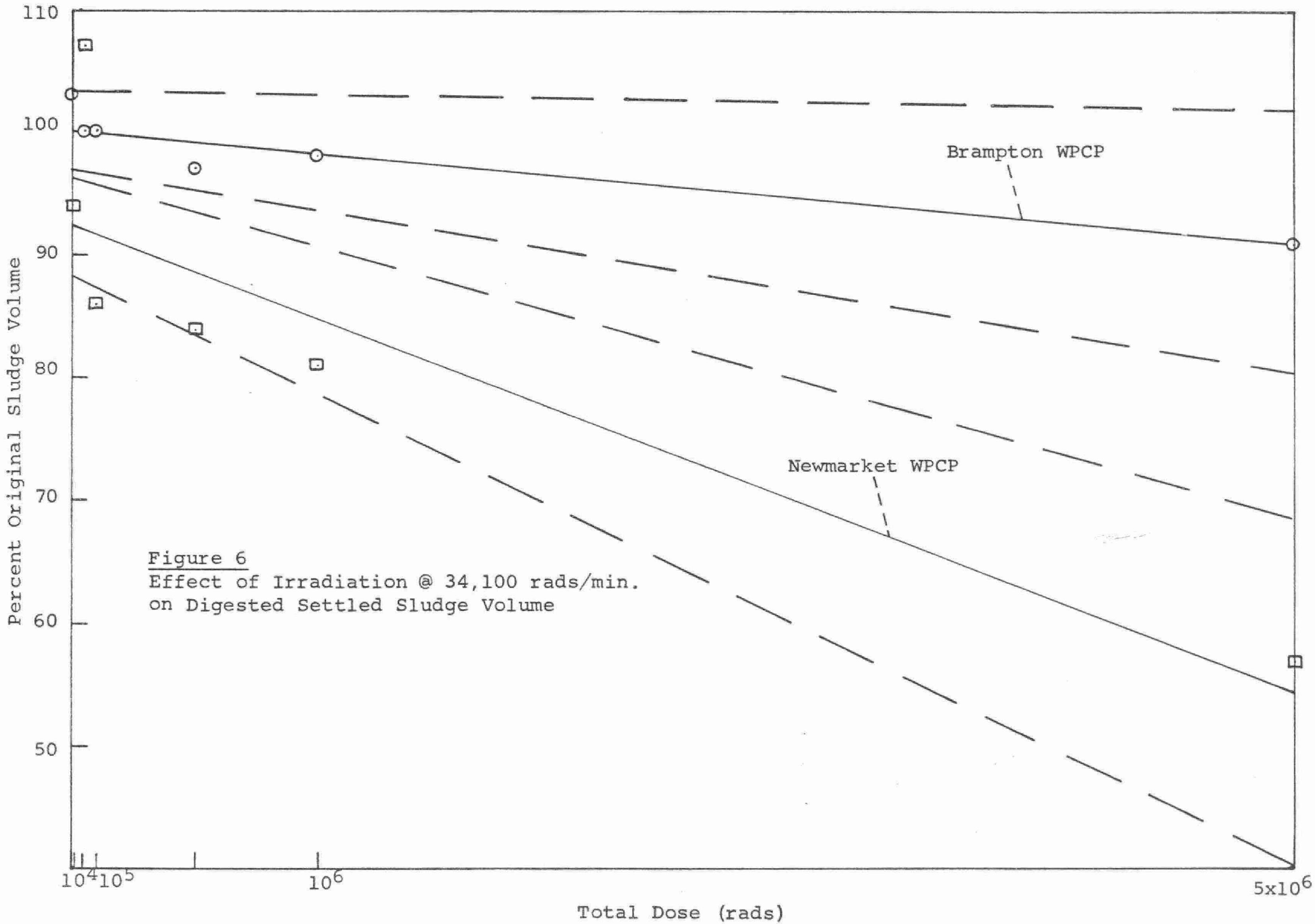


Figure 6
Effect of Irradiation @ 34,100 rads/min.
on Digested Settled Sludge Volume

dosage, an increase of nearly 240 percent supernatant suspended solids occurred in the Newmarket liquor.

Differences in effect of irradiation could be accounted for by the fact that in Newmarket sludge is wasted almost continuously to the primary digester, resulting in an overflow of a more actively separable sludge. The benefits of the reduced sludge volume and ultimate disposal cost should be compared to the cost of providing aeration to handle the heavier load by the stronger digester supernatant before the use of irradiation is considered.

2.2-4 Other Sewage Sludges

Irradiation of waste activated sludge from two model sewage treatment plants (6) set up in the laboratory produced no alteration in settling efficiency. One plant employed conventional activated sludge methods, the other used chemical addition of 200 ppm lime and 40 ppm ferric chloride to the raw sewage.

Raw primary sludge from Brampton was like a thick grey mud. Even the highest doses of irradiation could not produce any separation between the sludge and its liquid content.

3. Model Treatment Plant

3.1 Experimental Procedure

A model sewage treatment plant was designed for waste treatability studies (6) which would simulate conditions existing in full-scale plants. The plant operated on a continuous flow, combined aeration, sedimentation and sludge return system.

Irradiation experiments were limited to exposure of the raw sewage influent by pumping from a drum of fresh sewage through a copper coil lowered into the Gammacell and then into the aeration section of the plant.

The purpose of the study was to determine whether irradiation of the sewage influent affected the biological process in the model plant. The plant was run under normal conditions (no irradiation of raw sewage) for two weeks beginning with a 12 hour retention time which was then reduced to 9 hours. The raw lab sewage was then directed through the Gammacell 220 at a flow rate of approximately 75 ml/min. where it received a dose of approximately 29,000 rads at 6,950 rads/min. The plant was run for another two weeks in this manner. In the final four days of operation, the retention time and radiation dosage were lowered to 4.5 hours and 15,000 rads respectively.

Regular sampling of the influent and effluent took place twice daily for BOD and COD analyses. Sludge from the settling chamber was drawn off periodically and settled in a graduate. Dissolved oxygen values were determined on the mixed liquor in the aeration section, and microscopic examination of the sludge and mixed liquor was carried out once irradiation of the influent had begun.

3.2 Results

The data obtained from analysis of the influent and effluent quality was subjected to a 95% confidence test. The results showed a decided lack of consistency in the data. Irradiation appeared not to affect the model plants overall capacity to reduce BOD. The effect of a higher dose of irradiation was obscured by the relatively low BOD of the raw sewage influent. Reduction of COD was greater at the lower dose (15,000 rads); no significant change was observed with the higher dose. Sludge from the clarifier section settled between 10 and 16 percent total liquid volume with no alteration due to irradiation. Dissolved oxygen measurements on the raw sewage showed reductions between 40 and 70 percent after irradiation.

The overall operation of the model treatment plant was decidedly unsatisfactory. The dissimilarity in results could be due to either operational techniques (different detention times) or irradiation or both. A more reliable set of results should be obtainable if two plants were run in parallel; one receiving irradiated raw sewage, the other untreated influent.

IV DISCUSSION

The data obtained from irradiating sewage and sewage sludges at the two low rates (60 and 630 rads/min) showed that the amount of gamma bombardment available was insufficient to produce any significant reduction in settled solids volume. Even if high total doses of the low rate irradiation proved useful, the time necessary to reach this level would not be feasible in sewage stream or settling tank.

At a higher radiation rate (approximately 7,100 rads/min), a consistent reduction of settled solids volume in raw sewage was produced around 10^6 rads total dose. The sedimentation rate of waste activated sludge showed immediate positive response to all doses at this particular radiation rate. The intensity of the gamma photons was between ten and one hundred times that available from the two low rate sources resulting in an equivalently greater amount of energy for initiating reactions in the sludges. The energy available at this dose rate did not noticeably affect the biological metabolism of sewage in the model treatment plant.

At the highest dose rate (35,000 rads/min), significant changes were produced in sludge volume and supernatant quality. Around 10^6 rads total dose the volume of settled solids in raw

sewage was reduced to roughly fifty percent with little alteration in supernatant quality. Above this dose some physical or chemical alteration of the solids caused them to become more voluminous and even disperse to the supernatant as proved by an increase in suspended solids concentration. The decrease in BOD at this dose could be the result of production of less biodegradable compounds.

Sewage sludges were more sensitive to high rate irradiation. Their range of optimum response was between 5×10^4 and 10^5 rads above which either flotation of the sludge or dispersion of a large amount of solids to the supernatant occurred. Both effects would result in a poor quality effluent from an actual treatment plant. Temperature increases ranging from 5 to 15 centigrade degrees were produced in the sewage and sludges as a result of dissipation of radiant energy, depending on the time of exposure.

The type of sewage treated also affects its response to irradiation treatment. Raw sewage and mixed liquor collected from the Lakeview WPCP which contained a large percent of industrial effluent showed a quite consistent reduction in sludge volume with high rate dosing. Liquors obtained from treatment plants with mainly domestic influents (Brampton, Newmarket, Richmond Hill, and the Rexdale laboratory sewage line) showed

more erratic behaviour. The method of treatment plant operation would also influence the efficacy of radiation treatment. A plant with well-compacted sludges would not benefit greatly from a mechanism which stimulates sludge compaction. It appears that the waste streams from each individual treatment system should be submitted to jar tests and continuous radiation experiments in the laboratory before contemplating a full scale system.

V CONCLUSIONS

Within the limits of statistical reliability of the accumulated data, it was concluded that:

1. All doses of the lower rate irradiation (60 rads/min and 630 rads/min) had no significant effect on the settleable solids volume of raw sewage and sewage sludges.

2. Around 10^6 rads total dose of higher rate irradiation (7,100 rads/min) a significant reduction in settled solids volume of raw sewage was produced. The settling rate of waste activated sludge was improved at all doses of this radiation rate.

3. Total doses of high rate irradiation (35,500 rads/min) around 10^6 rads for raw sewage and between 5×10^4 to 10^5 rads in sewage sludges produced optimum settling effects in these media.

4. No conclusive evidence of enhanced biodegradability of sewage in a model treatment plant was found after exposure to 15,000 and 29,000 rads of gamma irradiation.

VI REFERENCES

(1) Ballantine, D.S., Miller, L.A., Bishop, D.F., and Rohrman, F.A. "The Practicality of Using Atomic Radiation for Waste Water Treatment". Journal WPCF, Vol. 41, No. 3, Pt. 1, March 1969 pp 445-458

(2) Stein, J.E., and Bacon, V.W. "The Overall Approach and Goal of the Chicago Sanitary District in the Use of Radiation". Am. Journal of Public Health, Vol. 59, No. 12 pp 2257-2263

(3) Etzel, J.E., Born, G.S., Stein, J.E., Helbing, T.J., and Baney, G. "Sewage Sludge Conditioning and Disinfection by Gamma Irradiation". Ibid, Vol. 59, No. 11, pp 2067-2076

(4) Touhill, C.J., Martin, E.C., Fujihara, M.P., Olesen, D.E., Stein, J.E. and McDonnell, G. "The Effects of Radiation on Chicago Metropolitan Sanitary District Municipal and Industrial Wastewaters". Journal WPCF, Vol. 41, pp R44-60

(5) Compton, D.M.J., Whittemore, W.C., Black, S.J., "An Evaluation of the Applicability of Ionizing Radiation to the Treatment of Municipal Wastewaters and Sewage Sludge". Trans. Amer. Nucl. Soc., 13:71-2 (June, July 1970)

(6) Black, S.A., "A Model Sewage Treatment Plant for Waste Treatability Studies", OWRC, Division of Research R.P. 2011, August 1967, 15 pgs.